MULTI-PARAMETER HEARING AID

Cross-Reference to Related Application(s)

This application claims the benefit of U.S. Provisional Application No. 60/474,744, filed on May 30, 2003, under 35 U.S.C. § 119(e).

Field of the Invention

The present invention relates generally to hearing aids, and more particularly, to a multi-parameter hearing aid.

Background

Hearing aids have parameters which, when adjusted appropriately, can improve the hearing aid performance for a specific person in specific environments. Such adjustable parameters include, for example, gain, maximum output, and compression ratio (the amount by which louder sounds should be reduced). Control of these parameters via the adjustment of potentiometers was, at one time, considered the industry standard.

Today roughly half the hearing aids sold in the U.S. are made using digital circuitry, and computer-control of the hearing aid's adjustable parameters is the norm. Computer programming of digital hearing aids allows for increased flexibility and precision in setting parameters. Furthermore, the number of parameters that can be adjusted is not constrained by the physical dimensions of the hearing aid. However, many users/dispensers of digital hearing aids do not have the computer access needed to adjust these devices. These users would be better served by potentiometer-controlled digital hearing aids. Currently, the small size of the hearing aid limits the number of potentiometers (and subsequently the number of parameters) to just two or three. There exists a need to increase the number of parameters than can be adjusted by potentiometer, rather than computer, control.

Summary

The present subject matter addresses the foregoing need and others not stated expressly herein. In varying embodiments, a hearing aid includes a 'parameter-select' device to select one of several parameters to be adjusted, and a 'parameter-adjust' device to adjust the parameter selected by the 'parameter-select' device. Another embodiment of the hearing includes an entire set of pre-programmed parameters to be selected for a given position of the parameter-select device Other embodiments of the hearing aid includes a memory select device to select first parameters in a first or second parameters in a memory device. Other embodiments are provided in the detailed description and will be discernable to those of skill in the art upon reading and understanding the present subject matter.

This Summary is an overview of some of the teachings of the present application and not intended to be an exclusive or exhaustive treatment of the present subject matter. Further details about the present subject matter are found in the detailed description and appended claims. Other aspects of the invention will be apparent to persons skilled in the art upon reading and understanding the following detailed description and viewing the drawings that form a part thereof, each of which are not to be taken in a limiting sense. The scope of the present invention is defined by the appended claims and their legal equivalents.

Brief Description of the Drawings

Figures 1A, 1B, and 1C each show a hearing aid housing according to an embodiment of the present invention.

Figure 2 is a block diagram of a circuit in a hearing aid according to an embodiment of the present invention.

Figure 3 is a block diagram of a memory map in a hearing aid according to an embodiment of the present invention.

Figures 4A and 4B are a flowchart of a method of operating a hearing aid according to an embodiment of the present invention.

Figures 5A, 5B, and 5C each show a hearing aid housing according to an embodiment of the present invention.

Figure 6 is a block diagram of a circuit in a hearing aid according to an embodiment of the present invention.

Detailed Description

In the following detailed description of embodiments of the present invention, reference is made to the accompanying drawings which form a part hereof, and in which are shown by way of illustration, specific embodiments in which the subject matter may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the subject matter, and it is to be understood that other embodiments may be utilized and that process, electrical or mechanical changes may be made without departing from the scope of the present disclosure. It should be noted that references to "an", "one", or "various" embodiments in this disclosure are not necessarily to the same embodiment, and such references contemplate more than one embodiment.

FIG. 1A shows a hearing aid housing 100 adapted to be worn behind an auricle of an ear 101 according to an embodiment of the present invention. A parameter-select device 102 and a parameter-adjust device 104 are located on an external surface of the hearing aid housing 100. FIG. 1B shows another embodiment where a hearing aid housing 110 is adapted for placement in the concha of an ear 112. A parameter-select device 114 and a parameter-adjust device 116 are located on an external surface of the hearing aid housing 110. In another embodiment of the present invention shown in FIG. 1C, a hearing aid housing 120 is adapted for placement in deeper in the auditory canal of an ear 122. A parameter-select device 124 and a parameter-adjust device 126 are located on an external surface of the hearing aid housing 120. Each of the hearing aid housings 100, 110, and 120 is supported by an ear according to alternate embodiments of the present invention. The parameter-select devices 102, 114, and 124 are the same

and will be referred to with the reference numeral 102. The parameter-adjust devices 104, 116, and 126 are the same and will be referred to with the reference numeral 104.

In one embodiment, the parameter-select device 102 is a parameter-select potentiometer 102 and the parameter-adjust device 104 is a continuous digital potentiometer 104. Other types of devices may be used for the parameter-select device and the parameter-adjust device according to varying embodiments. In one embodiment, the parameter-select potentiometer 102 comprises a Resistance Technology Incorporated Trimmer Model 17 and the continuous digital potentiometer 104 comprises a Microtronic Volume Control Model DCU 93. Other potentiometers may be used for the parameter-select potentiometer 102 and the continuous digital potentiometer 104 without departing from the present teachings.

A block diagram of a circuit 200 in the hearing aid housing 100 is shown in FIG. 2 according to an embodiment of the present invention. The circuit 200 is coupled to the parameter-select potentiometer 102 and the continuous digital potentiometer 104 shown in FIGS. 1A-1C. The circuit 200 includes a microphone 202 to receive sound 204 and to generate an input signal based on the sound 204. The circuit 200 also includes a receiver 206 to transmit sound 208 based on an output signal, and a digital signal processing circuit 210 coupled between the microphone 202 and the receiver 206 to process the input signal from the microphone 202 and the output signal to be transmitted to the receiver 206 according to a number of parameters. The parameter-select potentiometer 102 is used to select one of the parameters to be adjusted, and the continuous digital potentiometer 104 is used to adjust the selected parameter.

The digital signal processing circuit 210 includes a program connection 211 to receive instructions to be programmed into the digital signal processing circuit 210, a processor 212, an EEPROM 214 coupled to the processor 212, and an interface 216 coupled to the program connection 211, the processor 212, and the EEPROM 214 to relay the instructions to the EEPROM 214 and the processor 212. A first analog-to-digital converter 218 is coupled between the microphone 202 and the processor 212 to convert the input signal from the microphone 202 into a digital signal to be received by

the processor 212. A second analog-to-digital converter 220 is coupled between the parameter-select potentiometer 102 and the processor 212 to convert an analog signal from the parameter-select potentiometer 102 into a digital signal to be received by the processor 212 to select one of the parameters. A pulse detect circuit 222 is coupled between the continuous digital potentiometer 104 and the processor 212 to detect pulses generated by the continuous digital potentiometer 104 and to couple a signal to the processor 212 to indicate the detected pulses. A digital-to-analog converter 224 is coupled between the processor 212 and the receiver 206 to convert a digital signal from the processor 212 to the output signal to be received by the receiver 206. The receiver 206 includes two terminals 225 coupled to the digital-to-analog converter 224 to receive the output signal.

The microphone 202 includes a high terminal 227 coupled to a supply voltage Vss, a middle terminal 228 to couple the input signal to the first analog-to-digital converter 218, and a low terminal 230 coupled to a ground voltage reference.

The parameter-select potentiometer 102 includes a high terminal 232 coupled to the high terminal 227 of the microphone 202, the supply voltage Vss, and a first end of a resistor 234. A middle terminal 236 of the parameter-select potentiometer 102 is in movable contact with the resistor 234 and is coupled to the second analog-to-digital converter 220. A low terminal 238 of the parameter-select potentiometer 102 is coupled to a second end of the resistor 234 and to the ground voltage reference. The parameter-select potentiometer 102 is rotated to move the middle terminal 236 along the resistor 234 to generate an analog signal at the middle terminal 236. The analog signal indicates the position of the parameter-select potentiometer 102, and is converted into a digital signal by the second analog-to-digital converter 220.

The parameter-select potentiometer 102 includes a visible arrow 240 pointing toward the selected parameter, each parameter being represented by a visible color-coded dot 242. The color-coded dots 242 are fixed in relation to the parameter-select potentiometer 102 and represent the parameters including a low cut filter frequency LC, a high cut filter frequency HC, a compression ratio CR, a threshold knee TK, a gain

control GC, an output parameter AO, full-on parameters, and so called 'best fit' parameters. The parameter-select potentiometer 102 is rotated to indicate one of the color-coded dots 242 with the arrow 240. The parameter-select potentiometer 102 also includes an indentation 244 shaped to receive a screwdriver to rotate the parameter-select potentiometer 102.

The continuous, digital potentiometer 104 produces positive pulses 246 when rotated in a clockwise direction and produces negative pulses 248 when rotated in a counterclockwise direction. One full rotation of the continuous digital potentiometer 104 corresponds to an entire range of values for a parameter. The continuous, digital potentiometer 104 further includes an indentation 250 shaped to receive a screwdriver to rotate the continuous digital potentiometer 104.

One way to change the parameters based on the settings of the parameter-select potentiometer 102 and the continuous digital potentiometer 104 is to employ a memory map. A memory map 300 is shown in FIG. 3 according to an embodiment of the present invention. The memory map 300 is shown in relation to the parameter-select potentiometer 102 and the continuous digital potentiometer 104. The color-coded dots 242 are also shown with the symbols indicating the parameters. The memory map 300 is stored in the EEPROM 214 and includes a number of four-bit addresses 302, each four-bit address 302 to address one of the parameters. The memory map 300 also includes a range of values 304 between a high value and a low value for each of the parameters. The EEPROM 214 stores a separate pointer for each of the parameters, each pointer to point to a value in the memory map 300 for a respective parameter. The processor 212 processes the input signal and the output signal according to values in the memory map 300 pointed to by the stored pointers. The pulse detect circuit 222 generates a signal to be used by the processor 212 to modify the pointers. A pointer 306 is shown schematically in FIG. 3. The digital signal from the second analog-to-digital converter 220 is converted into the four-bit address 302 associated with the selected parameter by the processor 212.

The memory map is implemented by software stored in the EEPROM 214 according to an embodiment of the present invention. The memory map is implemented in hardware such as dedicated registers in other embodiments of the present invention. Varying embodiments may include combinations of hardware and software to achieve the map as provided herein.

When the parameter-select potentiometer 102 is rotated to point the arrow 240 toward full-on parameters FULL-ON, the processor 212 modifies the pointers stored in the EEPROM 214 to point to full-on values in the memory map 300, the full-on values comprising the low cut filter frequency LC set for maximum gain, the high cut filter frequency HC set for maximum gain, the compression ratio CR set to 1:1, the threshold knee TK set to 45 dBSPL, and the output parameter AO set to maximum. The pointers are modified according to full-on pointer data stored in the EEPROM 214.

When the parameter-select potentiometer 102 is rotated to point the arrow 240 toward best fit parameters BEST FIT, the processor 212 modifies the pointers stored in the EEPROM 214 to point to best fit values in the memory map 300. The best fit values are selected according to audiometric data or data for a typical user, and the pointers are modified according to best fit pointer data stored in the EEPROM 214.

The circuit 200 is operated according to a method 400 shown in a flowchart in Figures 4A and 4B according to an embodiment of the present invention. The method 400 starts in 401 and the parameter-select potentiometer 102 is rotated to select one of the parameters in 402. Positive pulses or negative pulses or both positive pulses and negative pulses generated by positive or negative rotations of the continuous digital potentiometer 104 are detected by the pulse detect circuit 222 in 404. The pointer for the selected parameter is read in 406 and modified to point to a next highest value in 408 each time a positive pulse is detected and the pointer is modified to point to a next lowest value in 410 each time a negative pulse is detected. The pointer is prevented from pointing to a value higher than the high value in 412, and the pointer is prevented from pointing to a value lower than the low value in 414. The pointer is stored in 416 when the parameter-select potentiometer 102 is rotated to select a new parameter. The

processor 212 processes the input signal and the output signal according to values in the memory map 300 pointed to by the stored pointers in 418 and the method 400 ends in 420.

Other systems for adjusting the parameters based on the settings of the parameter-select potentiometer 102 and the continuous digital potentiometer 104 are possible. In one embodiment, the settings of one or more of the potentiometers are used to calculate one or more parameter values by processor 212 or by other hardware and software.

Other variations and combinations of potentiometers, hardware, and software are possible without departing from the scope of the present teachings. For example, a hearing aid housing 500 adapted to be worn behind an auricle of an ear 501 is shown in FIG. 5A according to an embodiment of the present invention. A memory select device 502 is located on an external surface of the hearing aid housing 500. In another embodiment of the present invention shown in FIG. 1B, a hearing aid housing 510 is adapted for placement in a concha of an ear 512. A memory select device 514 is located on an external surface of the hearing aid housing 510. In another embodiment of the present invention shown in FIG. 1C, a hearing aid housing 520 is adapted to be placed in an auditory canal of an ear 522. A parameter-select device 524 is located on an external surface of the hearing aid housing 520. Each of the hearing aid housings 500, 510, and 520 is supported by an ear according to alternate embodiments of the present invention. The memory select devices 502, 514, and 524 are the same and will be referred to with the reference numeral 502.

In one embodiment of the present invention, the memory select device 502 is a pushbutton toggle switch 502 to generate a pulse when pushed. Other types of devices may be used for the memory select device.

A block diagram of a circuit 600 in the hearing aid housing 500 is shown in FIG. 6 according to an embodiment of the present invention. The circuit 600 is coupled to the toggle switch 502 shown in FIGS. 5A, 5B, and 5C. The circuit 600 includes a microphone 610 to receive sound 612 and to generate an input signal based on the sound

612. The circuit 600 also includes a receiver 614 to transmit sound 616 based on an output signal. The circuit 600 has a first EEPROM 620 to store first parameters and a second EEPROM 622 to store second parameters. The toggle switch 502 is used to select the first parameters in the first EEPROM 620 or the second parameters in the second EEPROM 622. The circuit 600 has a processor 630 coupled between the microphone 610, the receiver 614, the first EEPROM 620, and the second EEPROM 622 to process the input signal from the microphone 610 and the output signal to be transmitted to the receiver 614 according to the first parameters or the second parameters. The circuit 600 includes digital circuitry.

The circuit 600 also includes a program connection 640 to receive instructions to be programmed into the processor 630 and an interface 642 coupled to the program connection 640, the first EEPROM 620, and the second EEPROM 622 to relay the instructions to the first EEPROM 620 and the second EEPROM 622. The processor 630 is coupled to the interface 642, the first EEPROM 620, and the second EEPROM 622 to receive the instructions. An analog-to-digital converter 650 is coupled between the microphone 610 and the processor 630 to convert the input signal from the microphone 610 into a digital signal to be received by the processor 630. A pulse detect circuit 660 is coupled between the toggle switch 502 and the processor 630 to detect a pulse 662 generated by the toggle switch 502 and to couple a signal to the processor 630 indicating the detected pulse 662. A digital-to-analog converter 670 is coupled between the processor 630 and the receiver 614 to convert a digital signal from the processor 630 to the output signal to be received by the receiver 614.

The microphone 610 includes a high terminal 680 coupled to a supply voltage, a middle terminal 682 to couple the input signal to the analog-to-digital converter 650, and a low terminal 684 coupled to a ground voltage reference. The receiver 614 includes two terminals 690 coupled to the digital-to-analog converter 670 to receive the output signal.

The first EEPROM 620 includes full-on parameters to cause the processor 630 to process the input signal from the microphone 610 and the output signal to be

transmitted to the receiver 614 according to the full-on parameters when the first EEPROM 620 is selected, the full-on parameters comprising a low cut filter frequency set for maximum gain, a high cut filter frequency set for maximum gain, a compression ratio set to 1:1, a threshold knee set to 45 dBSPL, and an output parameter set to maximum.

The second EEPROM 622 includes best fit parameters to cause the processor 630 to process the input signal from the microphone 610 and the output signal to be transmitted to the receiver 614 according to the best fit parameters when the second EEPROM 622 is selected, the best fit parameters having been selected according to audiometric data or data for a typical user.

Although the present invention has been shown in several embodiments in relation to typical human ears and hearing, it is understood that these teachings may be applied in other hearing assistance devices, atypical ear shapes and non-human applications.

Although the present invention has been described in conjunction with the foregoing specific embodiments, many alternatives, variations, and modifications will be apparent to those of ordinary skill in the art. Other such alternatives, variations, and modifications may fall within the scope of the following appended claims or within the legal equivalents of the claims.